AN ANALYSIS OF THE US AUTOMOBILE INDUSTRY UNDER THE NEW FUEL ECONOMY STANDARDS: A PROJECTION

by

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ABSTRACT

The Energy Independence and Security Act of 2007 included updated fuel economy standards for light-duty vehicles in order to reduce the dependency on oil and emission of greenhouse gases in the US. The new Corporate Average Fuel Economy (CAFE) standards not only mandate higher fuel economy standards – measured as miles per gallon traveled – but also implement the standards in such a way as to stimulate technological innovation and competitiveness of the US domestic manufacturers relative to their Japanese counterparts. In this sense, the new legislation, a so-called attribute-based system defining CAFE standards individually with respect to type of vehicle, does not encourage downsizing as a path to achieving better fuel economies compared with what had been the case during the period of compliance with the 1975 standards.

The purpose of this study is to model the US automobile industry's path to compliance with the new higher CAFE standards. To model this transition, we will concentrate on Toyota and General Motors (GM), two leading manufacturers whose combined market share in the US is about 40% as of April 2008. Toyota and GM's certain characteristics make this selection fruitful. First, trucks make up a larger share of GM's production. Second, Toyota has a smaller fleet and the Prius technology to begin with that help Toyota meet the standards set for cars as of today. According to our projections, GM needs to undergo a more drastic transformation to meet

the standards set for 2015 by National Highway Traffic Safety Administration (NHTSA). Slightly smaller cars and trucks and technological innovation bettering the fuel economy of the pure gasoline-powered vehicles and the introduction of hybrids appear to be the recipe for hitting the 2015 standards. We conclude that CAFE standards stimulate technological innovation and help domestic manufacturers like GM stay competitive. However, the latter will also be dependent on the vehicle mix as consumer preferences shift towards smaller and more fuel-efficient vehicles.

This thesis is dedicated to:

my parents for their lifetime support,

my dear sister Tuce for being a great source of motivation, and

my other half Rojhat for years of love and inspiration.

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CHAPTER I

INTRODUCTION

In the fall of 2007 when oil prices reached 100 dollars a barrel without any prospect of falling back down soon, the need for government regulation to diminish dependency on oil consumption became more compelling than ever. Given that passenger cars and light-trucks (hereafter, 'light-duty vehicles') account for approximately 40% of all US oil consumption, updating 1975 fuel economy, or so called Corporate Average Fuel Economy (CAFE) standards, unsurprisingly found its way onto the policy agenda. Gasoline consumption of light-duty vehicles not only deepens energy issues but also has proved to be one of the primary sources of greenhouse gas emissions – 20% of total emissions – seen as responsible for global warming (Environmental Protection Agency, hereafter EPA).

These two major public concerns, energy security and climate change, were the main motivations behind the new legislation that proposed to mandate higher CAFE standards for motor vehicles, measured as 'miles per gallon' or MPG. To this end, Congress passed the Energy Independence and Security Act (EISA) in December 2007. The new legislation is seen as a major step to improve fuel economy of automobiles produced in the US. The new regulation on CAFE standards was meant to improve the previous standards enacted in 1975 by mandating for the first time

that the US automobile industry meet at least an average 35 mpg standard for all domestically produced cars and light-trucks (Sport Utility Vehicles or SUVs, pickup trucks, vans and minivans) by 2020. The new legislation means a 40% increase in fuel economy from the current industry average of 25 mpg.

Four months after the release of the regulation NHTSA, which sets fuel economy standards for cars and light-trucks sold by all manufacturers in the US and is responsible for reinforcing CAFE in cooperation with Environmental Protection Agency (EPA), proposed even more aggressive standards for automobile manufacturers to comply with. NHTSA's proposal, released on April 22, 2008, requires an average of 35.7 mpg for cars and 28.6 mpg for light-trucks to ensure a 36.1 mpg industry average for light-duty vehicles by 2015.

Historically speaking, improvements in automotive fuel economy led by 1975 regulation have been motivated by higher oil prices followed by supply shocks in the beginning of 70s. The first regulation introduced CAFE standards to automobile manufacturers in 1975. After the introduction of the first fuel economy standards in 1975, manufacturers managed to comply with fuel economy standards mainly by producing smaller and lighter vehicles, details of which will be discussed below. On the other hand, 2007 standards, which are 'attribute-based', will encourage producers to improve their vehicles' fuel economies by technological innovation instead of adjusting the size of their current fleet.

This thesis aims at answering the following questions:

(i) How have automobile manufacturers complied with 1975 CAFE standards?

(ii) What are the differences between the current and previous standards?

(iii) How do new standards work and stimulate innovation?

(iv) How will GM and Toyota achieve 2015 fuel economy targets set by NHTSA?

CHAPTER II

1975 CAFE STANDARDS

Introduction of fuel economy standards

The US Congress first introduced CAFE Standards as part of the Energy Policy and Conservation Act of 1975. This came about two years after Organization of Petroleum Exporting Countries' (OPEC) oil embargo started. As a result of the embargo, oil prices skyrocketed reaching $47.63 per barrel (in 2007 dollars) by 1975 up from $18.35 in 1970 and continued rising peaking at $82.70 by the end of 1981. As a response to the oil crisis, Congress introduced CAFE standards that applied to vehicles with the model year of 1978 and beyond. Automobile manufacturers were mandated to produce passenger cars with average 18 mpg by 1978 and gradually improve fuel economy up to 27.5 mpg for cars with model year of 1985 and beyond. The NHTSA was given the authority to set separate CAFE standards for light-trucks starting with model year of 1979.

Reaction to new CAFE standards

As result of both rising oil prices and the CAFE legislation, vehicle fuel economy rapidly increased from its 1975 levels throughout the early 1980s for both passenger cars and light-trucks. Passenger car fuel economy increased from 17 mpg

in 1978 to 22.2 in 1982, a more than 30% increase, while light-duty truck fuel economy rose from 13.7 mpg to 19 mpg during the same period. After 1982, improvements in fuel economy had slowed down and come to a halt. Specifically speaking, passenger cars reached their peak in 1988 at 28.2 mpg and light-trucks in 1987 at 20.5 mpg.

The pattern of fuel economy between 1975 and 2007 and its relation to car size/weight is illustrated in Figures 1 and 2. Fuel economy improvements between 1975 and 1987/8 could be attributable to a growing share of smaller/lighter cars and trucks as well as technological improvements by automobile manufacturers: "The rapid rise in fuel economy in the late 1970s was due to a mix of efficiency improvements and downgrading of utility in the form of reduced size, power and elimination of accessories and amenities (such as air conditioning)" (Nicholas P. Lutsey and Daniel Sperling, 2005 p. 8). As seen on Figures 1 and 2, vehicle weights declined sharply and reached their lowest point in 1987. During the same period, fuel efficiencies improved significantly and met the standards implying a strong correlation between weight and fuel economy.

How do we account for the slowdown from 1987/8 forward? One main reason for the slowdown after 1987/8 could be thought to be decreasing gasoline prices starting from 1982. The pattern of fuel economy between 1975 and 2007 and its relation to gas prices can be followed in Figures 3 and 4. In 1982 the oil prices reversed the trend displayed since 1973. If gas prices could be ruled out as a factor, CAFE regulations alone could be credited for fuel economy gains between 1982 and 1987.

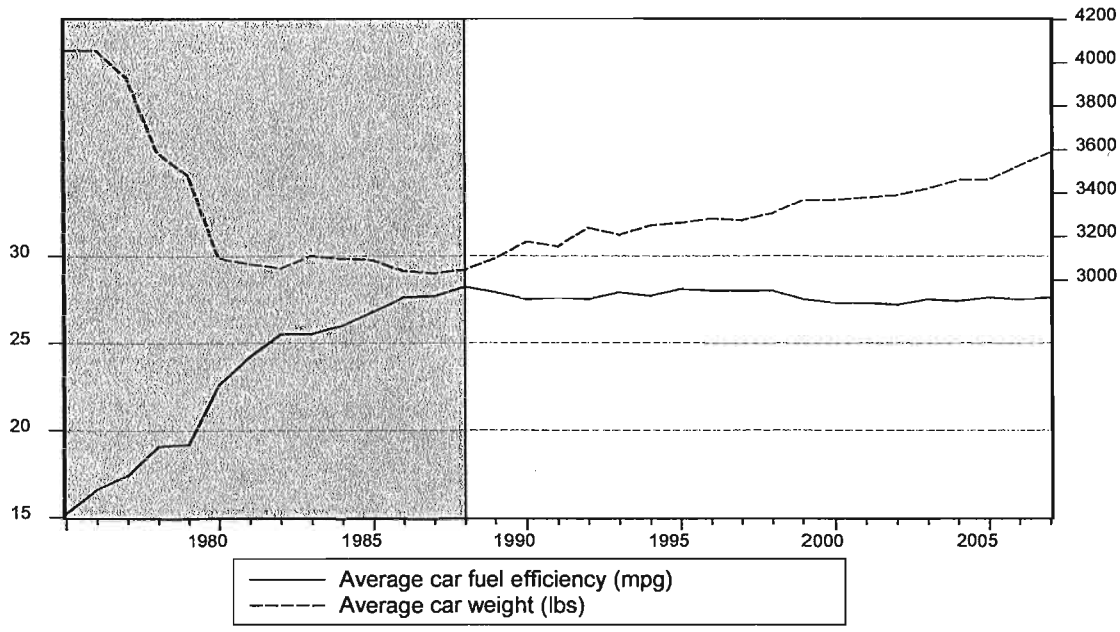

Figure 1: The interaction between 'average car fuel economy' and 'car weight' between 1975 and 2007
Source: US Environmental Protection Agency (2007)

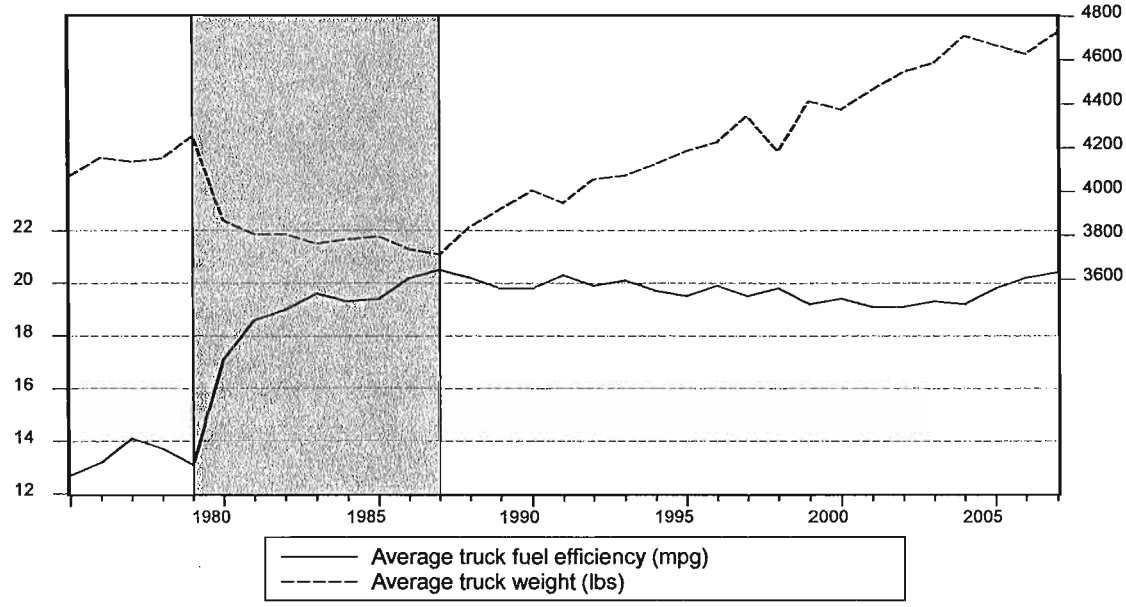

Figure 2: The interaction between 'average truck fuel economy' and 'truck weight' between 1975 and 2007
Source: US Environmental Protection Agency (2007)

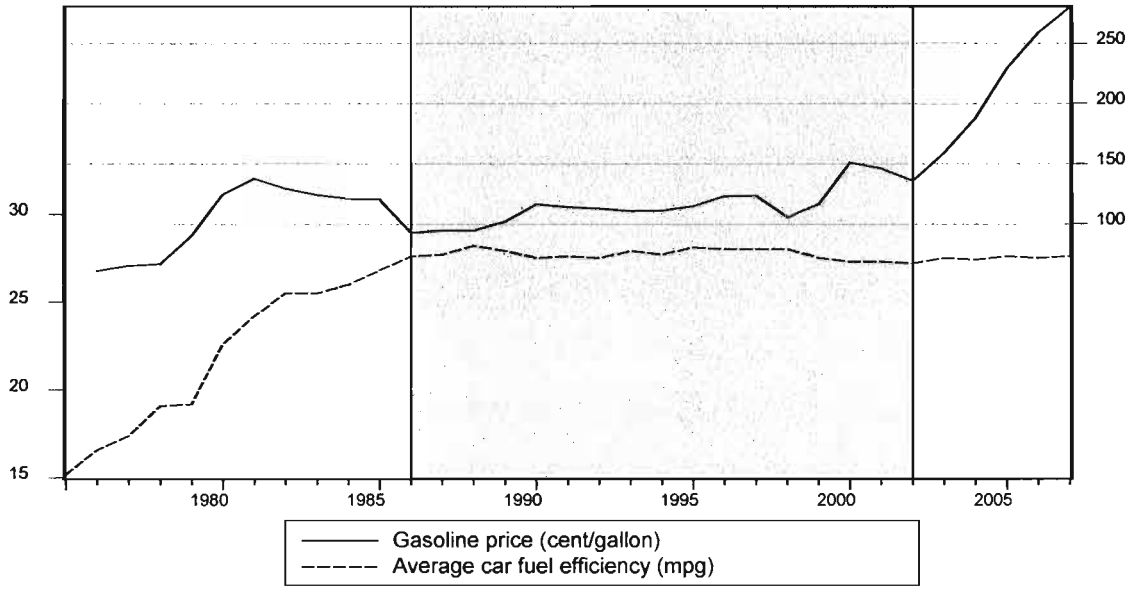

Figure 3: The interaction between 'average car fuel economy' and ' gasoline prices' between 1975 and 2007
Source: US Environmental Protection Agency (2007) and Energy Information Administration (2008)

As Paul R. Portney et al. (2003) put it,

> If the fuel economy improvements of the late 1970s and early 1980s were a response only to rising gasoline prices, we might have expected a gradual fall-off in fuel economy in the years following 1982; it is likely that the CAFE standards established a floor preventing such a decline. (p. 204)

Fuel economies had declined by average 9% between 1987/8-2004 as seen captured by the shaded areas on Figures 3 and 4. Stable oil prices and the lack of public pressure for higher CAFE standards have been responsible for the regress. The power of lobbying to oppose higher CAFE standards should also be mentioned.

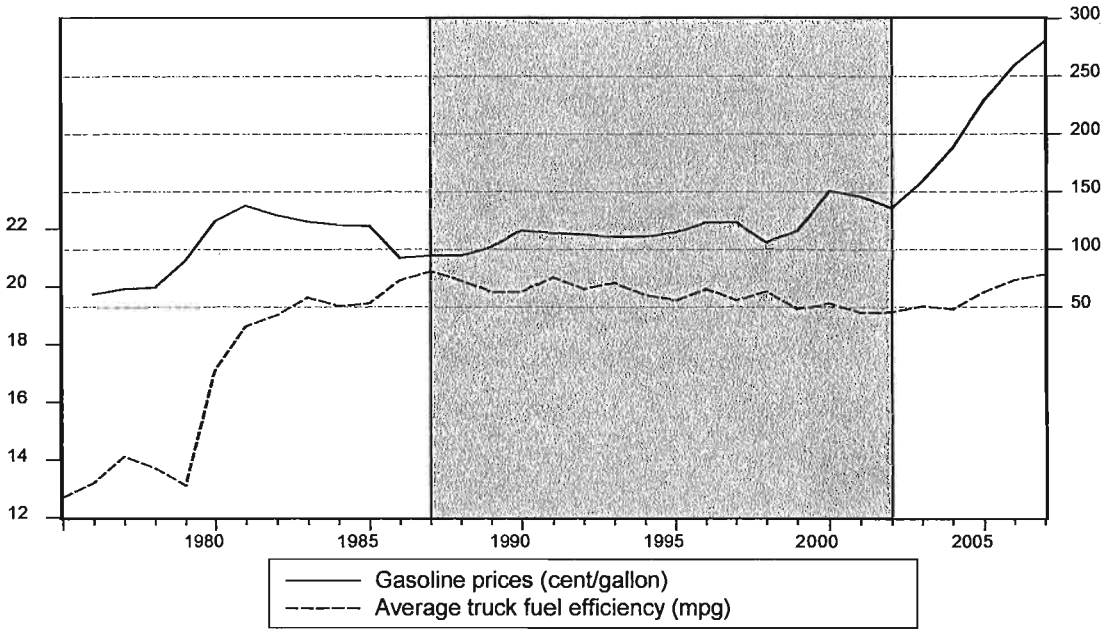

Figure 4: The interaction between 'average truck fuel economy' and 'gasoline prices' between 1975 and 2007
Source: US Environmental Protection Agency (2007) and Energy Information Administration (2008)

As Iain Carson and Vijay V. Vaitheeswaran (2007) argue,

> The bigger problem is that the industries do a brilliant job of conflating their narrow self interest with the larger national interests. In other words, oil and car bosses somehow manage to persuade Americans that what's bad for GM must be bad for America. And they have succeeded with this tactic because the Washington policy apparatus – its historical memory and its very soul- was formed back in an era when oil was seen not only as plentiful but also as desirable, domestically produced, and downright good for you. (p. 34)

During this lost decade in terms of fuel efficiencies, the U.S. automobile industry was not successful at technological innovations and bettering fuel economies any further to reach the goals set initially:

> ...efficiency improvements since the mid-1980s have been used in the United States to increase private benefits – more power, larger vehicles, and more accessories (including all-wheel drive) – and not for public benefits of reduced oil imports and greenhouse gas emissions. (Lutsey and Sperling, 2005 p. 17)

When the fuel economy standards were introduced in 1975, trucks constituted only 20% of all vehicle sales in the US. However, according to EPA's data, trucks climbed to be 51% of the light-duty vehicle production in 2007. Between 1975 and 2007 the biggest market share increase has been for SUVs, from 2% in 1975 to 29% in 2007. In the same period the share of car sales decreased from 70% to 50%.

After a period of stagnation in terms of fuel economy, the declining pattern was reversed where the combined average fuel economies of cars and light-trucks began to improve again from 2004 forward while oil prices were increasing steadily. "The increases in 2005 and 2006 are the first consecutive annual increases in fuel economy since the mid-1980s. This reverses a long trend of slowly declining fuel economy since the 1987 peak" (EPA, 2007 p. iii). EPA also points out that gains in terms of fuel economy in 2005 and 2006 were reached by technological innovations of manufacturers as opposed to the usual practice of weight reduction between 1975 and 1987. "Average light-duty vehicle weight dropped in both model years 2005 and 2006, with a slight increase in weight of cars was more than offset by a larger decrease in truck weight and a decrease in truck market share" (EPA, 2007 p. v). Expectations regarding higher oil prices and higher CAFE standards might have played a role in this anomaly. In the next decade as a result of new higher CAFE standards and increasing oil prices, better fuel economy levels are likely to be reached.

CAFE standards: GM and Toyota

As seen in Figure 5, GM displays a pattern that mimics the industry average in terms of fuel economy. After the peak of 1987, car fuel economies fluctuated with a slight upward trend approximating 30 mpg toward the end of the period. Meanwhile trucks stagnated until the last few years. Overall, improvement in combined fuel economy from 2004 forward was due merely to trucks.

Toyota displays a somewhat unusual pattern after the 1975 legislation. As seen in Figure 6, Toyota cars had already higher fuel economies to begin with and improved even further by 1985 hitting 30 mpg. Then fuel economies drop again, and conform to the rest of the industry.

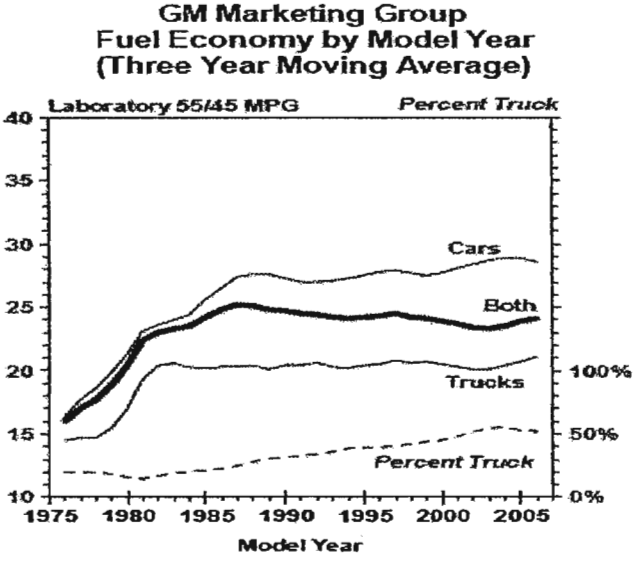

Figure 5: GM and fuel economy (1976-2006)
Source: EPA (2007)

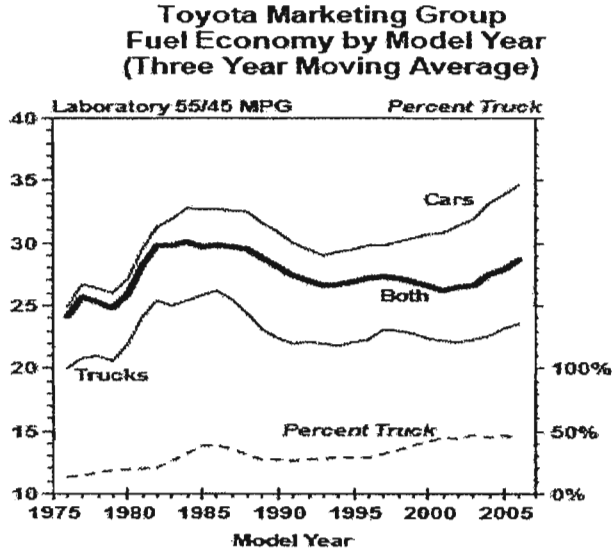

Figure 6: Toyota and fuel economy (1976-2006)
Source: EPA (2007)

However, unlike the rest of the industry, Toyota cars start improving again from the mid-90s on and approximate 35 mpg toward the end of the period. Toyota trucks display a similar, though less dramatic, upswing only a few years ago. Overall, the average fuel economy has significantly improved since the beginning of 2000.

CHAPTER III

ADVANTAGES OF NEW CAFE STANDARDS

In this chapter, we will compare the new CAFE standards with the former standards and also an alternative policy to reduce gasoline consumption, namely gasoline tax.

Drawbacks of 1975 CAFE standards

1975 CAFE standards set a single standard for cars (27.5 mpg) regardless of the manufacturer or relative size of the vehicle. This has encouraged automakers to change the composition of their fleet in favor of smaller cars to meet the standards. Since lighter vehicles tend to sacrifice safety, regulating automobile fuel economy has always been criticized by some.

> Klein et al. found that there was a 10 percent increase in fatality risk associated with a 1.000-lb reduction in vehicle weight in single-vehicle, non-rollover crashes ... The downsizing and weight reduction that occurred in the late 1970s and early 1980s most likely produced between 1,300 and 2,600 crash fatalities and between 13,000 and 26,000 serious injuries in 1993. However, the proportion of these casualties attributable to CAFE standards is uncertain. (NRC, 2002 p. 75-77)

However, new CAFE standards under a reformed "attribute-based" structure have changed the direction of the public debate on safety concerns.

> Because each vehicle model has its own target (based on the attribute chosen), attribute-based standards provide no incentive to build smaller vehicles simply to meet a fleet-wide average, because the smaller vehicles will be subject to more stringent fuel economy and emissions targets. (NHTSA, 2008 p. 137)

Therefore, the attribute-based system is expected to provide manufacturers with incentives to engage in technological improvements to better their fuel economy standards since "attribute-based standards are individualized for each manufacturer's different product mix" (NHTSA, 2008 p. 136). In other words, as vehicles get smaller the standards that apply to them would increase. This means that producing a lighter fleet would automatically require higher standards by limiting the ability to meet standards by merely changing the size of fleet. Consequently, "fuel savings and emissions reductions will always be higher under an attribute-based system than under a comparable industry-wide standard" (NHTSA, 2008 p. 136).

Why not a "gasoline tax"?

The main purpose of the new CAFE regulation is to reduce U.S. oil consumption in the long-term. The Congressional Budget Office (CBO) expects that changes in new CAFE standards will lead to reduction in the use of oil.

> As a result of the increase in CAFE standards for automobiles and light-trucks, CBO expects saving in motor fuel use by 2017 of over 5 billion gallons – or between 2% and 3% of total motor fuel use expected in that year without the change in law. (CBO, 2008 p. 8)

Once the ultimate goal is set to be fuel saving, one might wonder if there are alternative ways to achieve it besides higher CAFE standards. For example, The National Research Council (2002) suggested that higher gasoline taxes as an alternative to CAFE standards to accomplish the same end at lower cost. Because

> ...a tax increase would provide direct incentives for consumers to buy and for manufacturers to produce higher fuel-economy new vehicles and would also provide incentives to reduce the use of all new and existing vehicles" (NRC, 2002 p. 88). NRC also emphasized that... a gasoline tax would have an immediate broad impact on gasoline consumption ...(NRC, 2002 p. 93)

David Austin and Terry Dinan (2005) estimated that a 3.8 mpg increase in the CAFE standards will reduce gasoline consumption by 10% after 14 years. And then the authors investigated whether the same gasoline saving could be achieved with a higher gasoline tax:

> A tax designed to save the same amount of gasoline as the more stringent CAFE standards would accumulate savings much earlier because ... the tax would immediately discourage driving of new and old vehicles alike, in addition to encouraging the purchase of more fuel-efficient vehicles. (Austin and Dinan, 2005 p. 576)

Mark R. Jacobsen (2007) finds that "...increasing the stringency of CAFE will be much more costly relative to the amount of gasoline conserved and will fall disproportionately on domestic firms and low-income households" (Jacobsen, 2007 p.30). He goes on to support his argument with the following estimate:

> When simulating a one mile per gallon increase in the standard, I find that average household gasoline use is reduced by more than 3%. An examination of the gross welfare costs, however, suggests that the same reduction can be accomplished for less than one-sixth the cost by increasing gasoline taxes rather than using the CAFE instrument. (Jacobsen, 2007 p. 3)

Portney et al. (2003) survey arguments on, so-called, "rebound effects" as probable consequence of CAFE standards. Since higher CAFE standards will reduce gas bill per mile, more driving might be encouraged. Therefore, the authors conclude that because of this counteracting effect, increasing fuel economy standards would neither reduce oil consumption nor the carbon dioxide emissions as effectively as

projected by some. Even though these authors do not mean to make a case for a gasoline-tax proposal in their study, their arguments seem to provide support for that.

To sum up, the new legislation eliminates some of the drawbacks of the 1975 standards while having some advantages over higher gasoline tax policy whose details will be discussed in the following sections. Even though the new legislation might not discourage driving as effectively as a gasoline tax would, it

(i) would not seem to compromise safety, and promotes innovation instead of bettering fuel economies,

(ii) transition would not place the burden on consumers but manufacturers and be politically more acceptable,

(iii) would offer a longer period of transition for manufacturers, and

(iv) more importantly, seems to favor domestic manufacturers by forcing them to stay competitive.

CHAPTER IV

WHAT WILL THE TRANSITION TO THE CAFE LOOK LIKE?

In this section, we will survey several arguments (for and against CAFE) that might help us project the transition to the new legislation. We will analyze how profitability, consumers and technological innovation might respond to tighter CAFE standards.

CAFE and profitability

Andrew N. Kleit (2002) surveys major arguments opposed to tighter CAFE standards. The author believes that CAFE standards are poor policy tools to save gasoline and criticizes National Research Council's July 2001 Report that proposes 50% increase in CAFE standards for cars and light-trucks. Instead, he recommends, policy makers should consider raising gasoline tax. The author finds,

> … increasing the CAFE standards by 50% would cause far more harm to the economy. It would have reduced annual profits at General Motors by $3.824 billion, at Ford by $3.423 billion, and at Chrysler by $1.959 billion. Total losses to U.S. automakers would amount to $9.206 billion. In contrast, foreign manufacturers would see an increase in profits of $4.434 billion. Consumer surplus would decline $17.603 billion. (Kleit, 2002 p. 35)

Similarly, Rasha Ahmed and Kathleen Segerson (2007) survey empirical studies in the literature to show that CAFE regulations will affect the producers adversely:

> CAFE regulation has negatively affected producers' profit and that the automobiles industry continues to resist all attempts to tighten CAFE (Kleit, 1990, Leone and Parkinson, 1990, Goldberg 1998 and Kleit, 2002). Automakers claim that the new regulation that requires raising CAFE to 35 mpg by 2020, will cost them $83 billion (Taylor III, 2007). (Ahmed and Segerson, 2007 p. 6)

Despite the opponents of the new legislation, there is a growing number of authors supporting CAFE standards and projecting alternative scenarios through which the automobile industry will benefit from more stringent CAFE regulations.

Walter S. McManus (2007) suggests that new CAFE regulations could yield dramatically different impacts for the competitive position of individual automakers than the previous system. The report prepared for University of Michigan Transportation Research Institute (UMTRI) analyzes the economic impacts of legislative proposal of new CAFE standards before it became law. The main arguments of the report are the following:

Since reformed CAFE Standards set standards on a vehicle attribute basis such as size, companies with a higher share of larger vehicles (captured by larger footprints) in their production including the three biggest US automotive manufacturers, Ford, GM and Chrysler (the so-called Big 3) will face less stringent conditions. Detroit might end up gaining in terms of market share and profits under the new fuel economy standards. McManus projects, for example, GM's whole fleet, cars and trucks combined, to be 33.4 mpg on average. The same figure will be 37.5 mpg on average for Toyota for the industry target of 35 mpg to be reached by 2020.

This will improve the competitive position of the American automakers and their workers.

McManus also sees the new standards as a 'win-win' game.

> Higher standards will require automakers to install more expensive equipment on vehicles; however, higher initial costs will be more than offset by fuel savings. For example, the cumulative cost of raising fuel economy to 35 mpg by 2018 is $0.51 per gallon saved—about one-sixth of today's fuel price. (McManus, 2007 p. 3)

He goes on to argue that "higher CAFE standards can increase vehicle profits since vehicle prices will need to rise to pay for added fuel-saving technologies, and profits per vehicle will also rise (assuming ordinary profit margins)." However, he also mentions a partial offset that might be caused "by slower growth in total vehicle sales caused by the higher prices."

American producers facing lower CAFE standards will benefit the most:

> ... with product portfolios that are more concentrated in vehicle segments with lower fuel economy and higher prices (SUVs and pickups), Detroit automakers will be making improvements that have higher market value and higher profit margins. Their profits will be correspondingly higher. (McManus, 2007 p. 4)

As rising fuel prices encourage a switch to more fuel efficient cars on the part of consumers, the compliance with 2007 CAFE standards will help domestic producers to better their fleet to serve this growing demand.

CAFE and consumers

In the literature there is also ongoing debate as to how consumer decisions and welfare might be affected by higher fuel economy standards. Do consumers consider gasoline costs and prefer the models with higher miles per gallon? According to

Thomas S. Turrentine and Kenneth S. Kurani (2006), car buyers do not pay close attention to the share of gasoline costs in their household budgets. The authors used data retrieved through semistructured interviews with 57 households across nine lifestyle ''sectors''. They go on to argue, this is mainly because "they do not have the basic building blocks of knowledge assumed by the model of economically rational decision-making, and they make large errors estimating gasoline costs and savings over time" (Turrentine and Kurani, 2006 p. 12-13).

The research concludes that consumer reaction to higher gasoline prices and fuel economy standards might prove to be different from what experts and economic models expect. Nevertheless, one might fairly argue that this will likely change in the face of $4.00 per gallon fuel in the U.S.

Contrary to this view, McManus (2006) by estimating a hedonic regression with data on sales, prices, and attributes of vehicles in 2005 finds that consumers are willing to pay, on average, $578 more for one mile per gallon improvement:

> At the price of gasoline prevailing in 2005, $2.30 per gallon, the $578 per mpg that consumers are willing to pay for fuel economy implies that consumers put more weight in choosing vehicles on future fuel savings than most analysts (including ourselves) had thought. (McManus, 2006 p. 2)

Given that gas prices nearly double its 2005 levels, this 'willingness to pay' can be safely expected to be even higher in the future – which gives manufacturers an additional motivation to better their fuel economies to stay competitive.

Similarly, Molly Espey and Santosh Nair (2005) suggest that automobile consumers accurately value the fuel cost savings associated with improvements in

fuel economy. Their research indicates that consumers are behaving rationally in this very sense.

> This research might also help in understanding decisions regarding adoption of alternative technologies such as hybrid vehicles. This research suggests that consumers are likely to accurately value fuel cost savings associated with such vehicles, leading to rational adoption based on fuel cost savings, at least once they become more informed about and familiar with the features of such vehicles. Of course, other benefits such as reduced pollution, reduced global warming, or reduced energy dependency may also be associated with improved fuel economy, and while this research cannot determine why people value fuel economy, it has nonetheless found that they do positively value it and pay for it via higher automobile prices, all else being equal. (Espey et al., 2005 p. 223)

CAFE and innovation

Hybrid vehicles that combine a gasoline engine with an electric motor and battery system may comprise more cars in the future due to their higher fuel economy levels. How quickly the percentage of hybrids increases will be dependent on willingness to pay on the side of consumers and on future gasoline prices. It seems today that production of hybrid cars will increase in the next years as a transition to the legislation.

Since 2000 there has been an increase in hybrid car production. According to Kelly Sims Gallagher and Erich Muehlegger (2008) rising gasoline prices have given rise to higher hybrid sales.

> In 2000, the Honda Insight and Toyota Prius were the only hybrid vehicles available and collectively sold fewer than 3,000 units. Over the next six years manufacturers introduced nine other models. Honda launched hybrid versions of the Civic and Accord in 2002 and 2004, and Ford introduced a hybrid version of the Escape small SUV. In 2005, the Lexus RX400h, Toyota Highlander, and Mercury Mariner were launched, and in 2006, the Lexus GS450H, Saturn Vue, and Toyota Camry hybrid debuted. Sales have risen substantially – by

> 2006, more than 250,000 hybrid vehicles were sold. (Gallagher and Muehlegger, 2008 p. 3)

Government put in place new incentives such as tax credits in 2000 to stimulate consumer adoption of hybrid technology. Gallagher and Muehlegger (2008) analyzed the role of federal and local incentives in promoting hybrid sales. Their paper suggests that tax incentives and rising gasoline prices combined with social preferences are associated with 6, 27 and 36%, respectively, of economy hybrid sales from 2000 to 2006. Recent CAFE regulations seem to accelerate the switch to hybrid sales in coming years. David L Greene et al (2004) estimated possible increase of hybrid sales by 2012 even in the absence of any new CAFE standards and current tax incentives. The results are below:

> By 2008, hybrids could capture 4-7% of the light-duty market. These shares could increase to 10-15% for hybrids and 4-7% for diesels by 2012. The resulting impacts on fleet average fuel economy would be about +2% in 2008 and +4% in 2012. Hybrids must reduce costs to roughly half the cost increment of the first generation hybrids, a goal they are well on their way to reaching. If they can achieve these goals, diesels and hybrids should be able to capture 7-10% of the U.S. light-duty vehicle market by 2008, and 15-20% by 2012. (David L Greene et al, 2004 p. 55)

P. M. Flynn Hammet et al. (2004) also suggest that there will be many more hybrids and advanced diesels sold, as many as 1.8 million more, in the US in the 5 to 8 years from 2004.

Long-term plans announced by Toyota and GM, manufacturers on which we will concentrate, seem to provide support optimistic scenarios regarding share of hybrids. GM's Chairman Rick Wagoner has announced that GM will increase overall fuel economy improvements up to 20% by introducing a second-generation version of the current GM hybrid system. By the end of 2008, GM will offer eight hybrid

models in North America and nine worldwide as stated in its March 4, 2008 press release. It was also indicated in GM's 2007 Annual Report that between 2007 and 2010, GM is planning to introduce 16 new hybrid vehicles with an average of one every three months.

Increasing demand for hybrid electric vehicles as a result of higher gasoline prices and declining preference for light-trucks in the US market are expected to motivate manufacturers to introduce new hybrid light-trucks alongside hybrid cars. By the end of 2008 GM will introduce three hybrid SUVs: 2008 Saturn VUE Green Line Hybrid with 32 mpg, 2008 Chevy Tahoe and GMC Yukon Hybrid expected to deliver 50% better city fuel economy as announced by GM.

Toyota has been the market leader in terms of investment in new technologies to better fuel economies. Toyota's hybrid electric car Prius, first introduced in 1997, is becoming mass-produced today. As expressed in EPA's 2007 Fuel Economy Guide, Toyota Prius with 45 mpg (highway) standard is the most fuel-efficient car in the US automobile market gaining significant popularity among consumers with best-ever April sales of 21,757 units in 2008, an increase of 53.8% over last April.

> Toyota had learned how to make very efficient cars that appeal to consumers, who keep coming back for more. Instead of having top-heavy corporate structure with lots of divisions and different brands and dealer networks, like Ford and GM, Toyota kept itself quite simple. Its basic models such as the Corolla and Camry sell around the world, with only minor modifications for different markets. That way, it gets huge economics of scale. (Carson et al., 2007 p. 114)

Toyota will expand its hybrid mix in the future to stay competitive in the market as stated in their North American Environmental Report:

> We have steadily increased our hybrid product offering since the Prius was first introduced in North America in 2000. We now have three

> Toyota hybrids (Prius, Highlander Hybrid and Camry Hybrid), and three Lexus hybrids (RX 400h, GS 450h and LS 600h L). We anticipate combined sales of Toyota and Lexus hybrids of quarter million units in North America during calendar year 2007. (2007 p.16)

Toyota may become more ambitious in the future by producing cheaper hybrid cars in order to keep its competitive advantage and leadership in terms of fuel economy improvements in the market. Toyota's executive Vice President Masatami Tokimoto said that "he expected hybrids to become the standard drive train and account for 100 percent of Toyota's vehicles by 2020" (International Herald Tribune, 2008).

CHAPTER V

HOW WILL TOYOTA AND GM COMPLY WITH THE NEW CAFE STANDARDS?

The research question that we raise is the following: How will automobile manufacturers achieve the fuel economy target suggested by NHTSA for 2015? We will concentrate on Toyota with market share of 17.5% (up from 15.8) and GM with market share of 20.7% (down form 23.1) as representatives of Japanese and American manufacturers, respectively. To this end, we discuss some scenarios through which the standards set for these two market leaders could be achieved by 2015. Before representing projections we will carry out about the transition to the new legislation, we will explain how CAFE actually works together with the presentation of the current status of actual fuel economies and our data source and methodology.

How do new CAFE standards work?

The attribute-based system relates fuel economy standards to vehicle footprints. A vehicle's footprint is basically a proxy for the size of the vehicle. NHTSA defines "footprint" as the average track width (the distance between the centerline of the tires) multiplied by wheelbase (the distance between the centers of the axles). "Each vehicle footprint value is assigned a mile per gallon target specific to that footprint value" (NHTSA, 2008 p. 138).

The new attribute-based CAFE standards suggest the following function/formula that calculates the minimum fuel economy targets set individually for each vehicle as the function of its footprints.

$$T = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)/d}}{1+e^{(x-c)/d}}}$$

where

T = the fuel economy target (in mpg)

a = the maximum fuel economy target (in mpg)

b = the minimum fuel economy target (in mpg)

c = the footprint value (in square feet) at which the fuel economy target is midway between a and b[159]

d = the parameter (in square feet) defining the rate at which the value of targets decline from the largest to smallest values

e = 2.718[160]

Parameters of the formula, a, b, c and d, are given by NHTSA (2008) which change with year and whether the vehicle is categorized as 'car' or 'light-truck'. The function suggests a negative correlation between the footprint (or the size) of the vehicle, captured by x above, and its mpg. In other words, as the vehicle gets smaller the function mandates a higher mpg, as seen in the Figure 7. For instance, a 2008 Chevy Impala with a footprint of 55.94 should comply with 31.15 mpg by 2015 and is currently at 29 MPG. For the Toyota Yaris 2008 with footprint of 44.88, the CAFE standard is 36.91 in 2015. As seen in this example, size makes a difference.

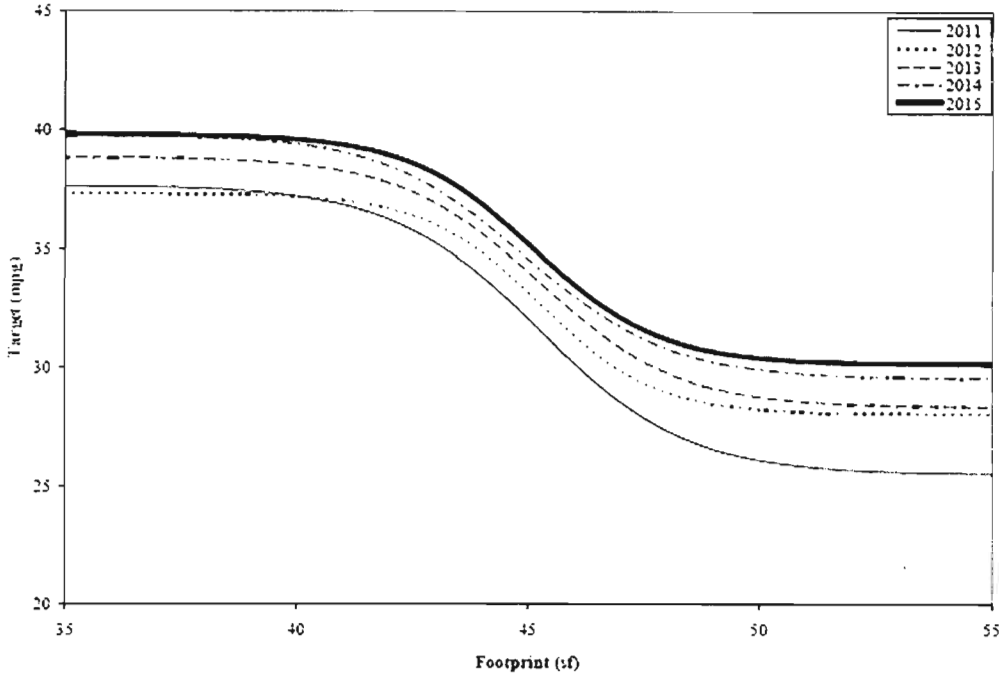

Figure 7: Fuel economy standards as function of footprint
Source: NHTSA (2008)

Model, methodology and data

To model the transition of Toyota and GM to the new CAFE standards, we focus on the total vehicle sales and mix in January through April of 2008. To simulate the consequences of several alternative scenarios, we work with a (best-seller) representative sample that consists of around 80% of total sales. This provides us the vehicle mix (e.g., % of trucks in total sales) and the average footprints that we need in calculating the discrepancy between the actual mpg today for each fleet and their required mpg by 2015.

To simplify the analysis, we define and calculate "average car footprint," "average car actual mpg," "average truck footprint" and "average truck actual mpg" that are expected to be representative of the whole fleet of cars and trucks.

"Averages" are footprints and actual fuel economies weighted by sales of each brand's cars and trucks, included in the sample calculated as follows. Calculated values are given in Table 1:

Average footprints = (Footprint of Vehicle A) x (Vehicle A sales/total sales) + (Footprint of Vehicle B) x (Vehicle B sales/total sales) + …

Average fuel economy (as highway mpg) = (Actual fuel economy of Vehicle A) x (Vehicle A sale/total sales) + (Actual fuel economy of Vehicle B) x (Vehicle B sale/total sales) + …

Vehicle mix appears to be 43% trucks and 47.5% cars and 9.5% hybrids for Toyota while, as shown in Table 1, 54.8% trucks and 45.2% for GM without any significant hybrid presence. In comparison, Toyota has a smaller fleet in both categories and more favorable fuel economies but is expected to be subject to higher CAFE standards than GM to begin with.

Table 1: Fuel economy levels for Toyota and GM vehicles and percentage of trucks in total sales as of 2008 April

	Avg. car' footprint	Avg. car' fuel economy	'Avg. truck' footprint	'Avg. truck' fuel economy	% of trucks	% of cars
Toyota	50.12	35.04 mpg	0.03	23.05 mpg	3	57
GM	53.68	30.07 mpg	3.83	21.25 mpg	4.8	45.2

Based on the vehicle mix and sales as of April 2008, Toyota and GM can be calculated to have the actual fleet averages summarized in Table 2 by using the following formula:

$$\frac{Total\ Production\ Volume}{\frac{\#VehicleA}{FuelEconomy}+\frac{\#VehicleB}{FuelEconomy}+\frac{\#VehicleC}{FuelEconomy}}$$

Table 2 summarizes (i) actual fuel economies for cars and trucks, (ii) the required fuel economies calculated by the CAFE function if the very same fleets and vehicle mix had been produced in 2015, (iii) the standards which NHTSA mandates Toyota and GM to meet by 2015 and finally (iv) combined fleet mpg once the 2015 standards were met.

Table 2: The discrepancy between actual fuel economies today and 2015 targets set by NHTSA, and expected fuel economies for the combined fleet by 2015

	Actual fuel economy (mpg)	Fuel economy defined by 2015 CAFE function (mpg)	NHTSA 2015 required CAFE standards (mpg)	Combined fleet average (mpg)
Toyota car	35.04	31.38	34.6	31.5
Toyota truck	23.05	25.80	28	
GM car	30.07	31.25	34.7	30.3
GM truck	21.26	25.08	27.4	

Fuel economy of Toyota cars appears to exceed the standards set by NHTSA for 2015, 34.6. Relatively speaking, GM seems to need a more drastic change in technology, especially in its light-truck division, to achieve these CAFE targets.

This can be seen in the discrepancy between the actual fuel economies of today (30.07, 21.26) and 2015 standards (34.7, 27.4).

Let us briefly explain what the second column in Table 2 represents. Given average footprints, the defined fuel economies for average car and truck can be calculated plugging the average footprints into the CAFE function. This illustrates how attribute-based CAFE standards work. There seems to be a gap, except for Toyota in the car category, between fuel economy defined by the CAFE function and NHTSA targets for 2015 provided on Table 2. What does it mean? An immediate implication could be thought to be following: improving the current mix of vehicles to comply with the 2015 standards suggested by the CAFE function will not be sufficient to meet the targets set by NHTSA for 2015. This simply means Toyota and GM will have to do more than make the existing fleet more efficient up to standards implied by the CAFE function. In this context, we will bring forward two options: (i) smaller vehicles and (ii) increasing hybrid car and truck production.

The last column in Table 2 was calculated by using the following formula where Ni and Ti represent shares of each vehicle in the fleet and required CAFE standards for each vehicle. We normalized N to 100.

$$Required\_Fuel\_Economy\_Level = \frac{N}{\sum_i \frac{N_i}{T_i}}$$

Simulations

In the rest of the study, we carry out some projections through which we will discuss how 2015 targets could be attained with a comparative perspective. We assume that manufacturers will meet the 2015 standards by producing smaller and higher-mpg (pure-gasoline-powered) vehicles as well as increasing the share of hybrid vehicles in their fleet. In other words, while average cars and trucks get smaller and more fuel-efficient, hybrid cars and trucks begin claming a larger share of total sales helping manufacturers better their average fuel economies for cars and trucks. To calculate steady annual changes in footprints and percentages of hybrid vehicles we used iteration as a method. We first calculate final values of these variables that help Toyota and GM achieve 2015 standards. Secondly, we reason backward to find out annual changes in the variables that would produce these final values by using the following exponential growth formula where r and t denote percentage change and year, respectively:

$$(\text{Initial value})e^{r.t} = \text{final value}$$

CASE 1: How far are Toyota and GM from meeting 2015 standards?

As summarized in Figure 8, Toyota has already exceeded the 2015 standards in the car category and requires improving fuel economy for the truck category annually by 2.9% to meet the standards by 2015. On the other hand, GM cars and trucks are required to improve by 1.21% and 3.7% each year, respectively.

Eventually, if the current vehicle mix is retained, the fuel economy for cars and trucks combined is calculated to be 31.52 mpg for Toyota and 30.31 mpg for GM with both below the required industry average of 31.6 by 2015 as seen in Figure 9. Toyota seems to have a much smoother path in complying with 2015 CAFE standards.

CASE 2: Cars and CAFE standards

As mentioned before, improving vehicles up to the fuel economy standards defined by the CAFE function (with 2015 parameters) would fall short of the NHTSA standards set for 2015. This could be thought to imply that cars are expected to be relatively smaller in size and the percentage of hybrids is expected to grow in total production for compliance.

Under this case, we will simulate this option for GM cars – not Toyota since it has met the 2015 standards already. According to the new CAFE standards, vehicles are required to be more fuel-efficient as their footprints, as proxy for their size, decline. At this point, we ask the following question: Given the composition of the current car fleet, to what percentage should hybrid sales climb to achieve the 2015 target (34.7 mpg) as footprints decline 1% a year?

As followed in Figure 10, the average car size will decline to, as a virtual approximation, that of Pontiac Vibe 2008 by 2015. Meanwhile, GM car sales will decline by around 5% annually while 45-mpg hybrid car sales will gradually rise to 31.5% of total car sales to comply with the CAFE standards.

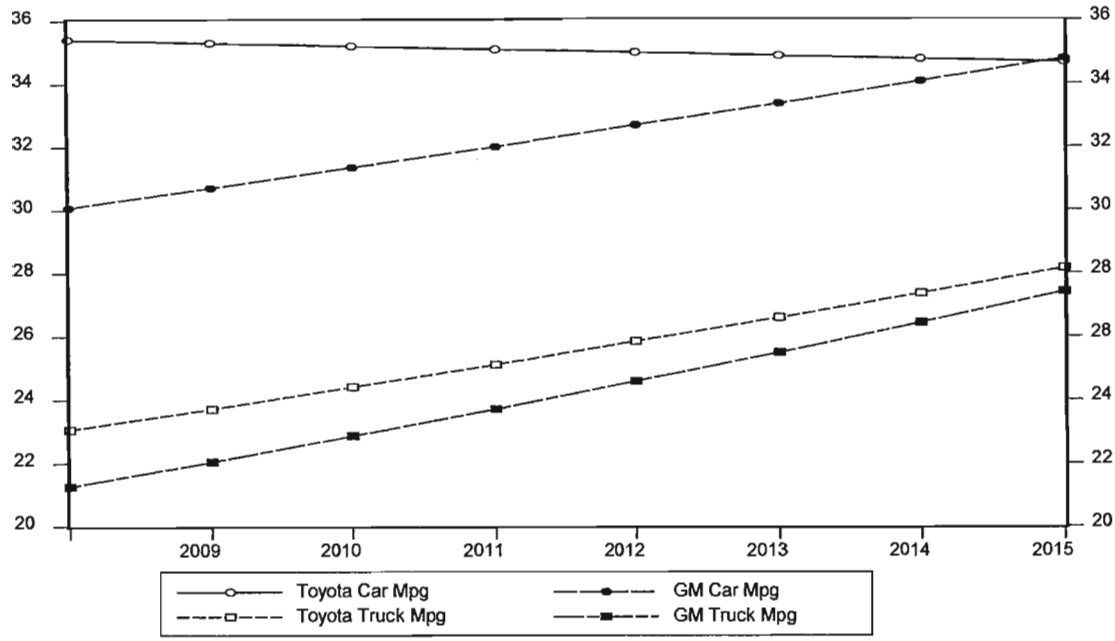

Figure 8: Compliance of Toyota and GM with 2015 standards for cars and trucks
Source: Kelley Blue Book (2008), http://www.gm.com, http://www.toyota.com

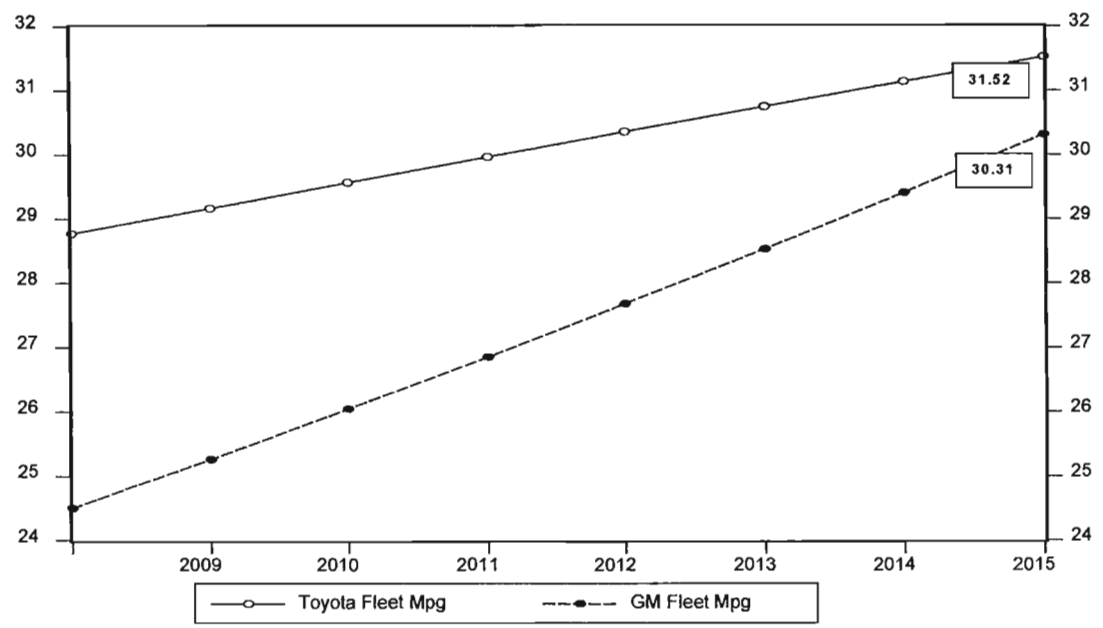

Figure 9: Toyota and GM combined fleet fuel economies by 2015 as the compliance takes place
Source: Kelley Blue Book (2008), http://www.gm.com, http://www.toyota.com

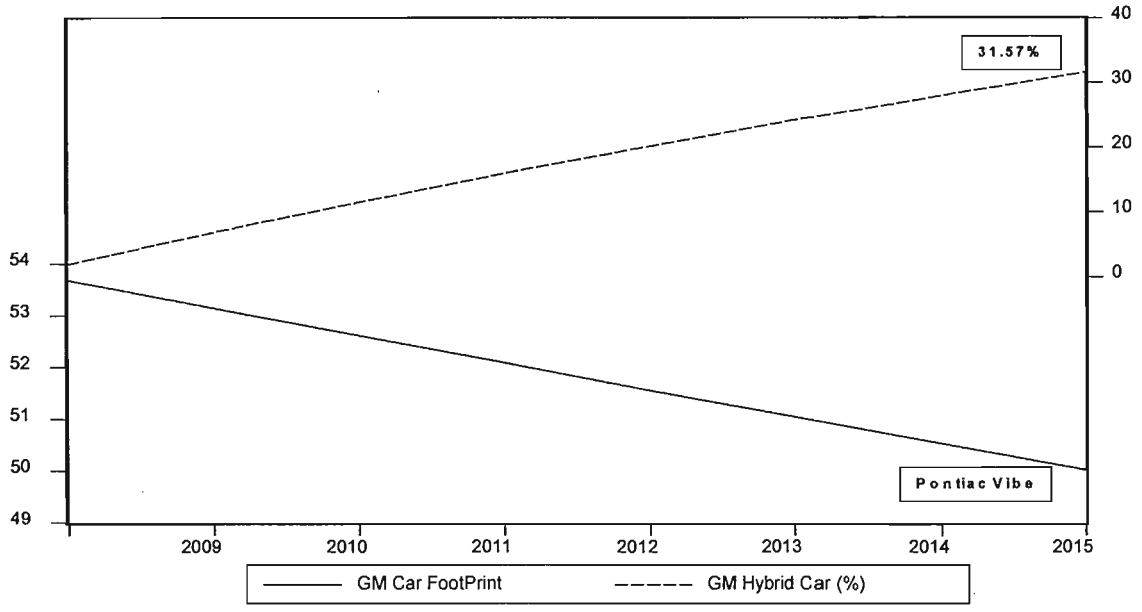

Figure 10: Necessary change in the share of hybrids, and footprints to comply with 2015 targets set for cars
Source: Kelley Blue Book (2008), http://www.gm.com, http://www.toyota.com

CASE 3: Trucks and CAFE standards

Similar to the experiment carried out under Case 2, we will simulate percentages of hybrids in total truck sales that allow Toyota and GM to comply with the fuel economy standards set for trucks by 2015 as footprints decline 1% a year.

As seen in Figure 11, the average truck size will decline to, as a virtual approximation, that of Highlander SUV 2008 for Toyota and Chevy Trailblazer 2008 for GM by 2015. Meanwhile, Toyota and GM regular truck sales will decline by around 4% and 4.5%, respectively, each year while 32-mpg hybrid truck sales will gradually rise to 25.1% and 28.3% of total truck sales, respectively, to comply with the NHTSA standards set for trucks.

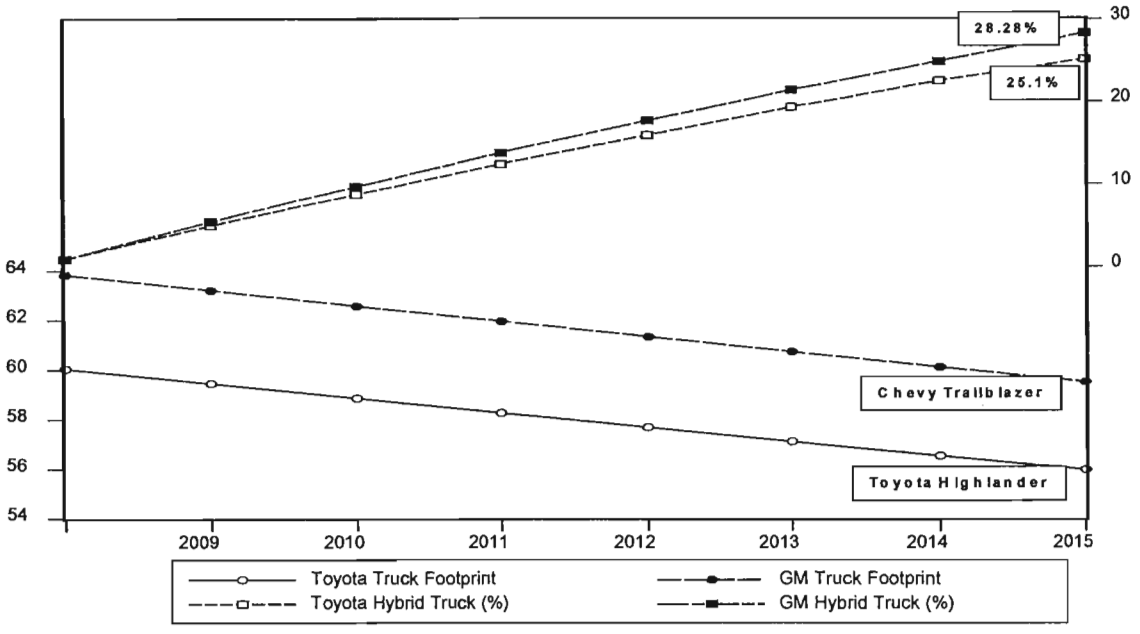

Figure 11: Necessary change in the share of hybrids, and footprints to comply with 2015 targets set for trucks
Source: Kelley Blue Book (2008), http://www.gm.com, http://www.toyota.com

Conclusions

Toyota and GM's future path

NHTSA has set similar standards for GM and Toyota in both categories. In the category of cars, Toyota has already met the standards. GM needs to improve its cars by on average 1.21% each year to comply with the standards by 2015. Toyota seems capable of going beyond the CAFE standards in this category on its current path. As for trucks, both Toyota and GM have a similar path in adjusting the new standards set for category.

Combined fleet average and cost of adjustment

At the end of the adjustment process, the fuel efficiencies for the whole fleet – cars and trucks combined – will be realized as 31.5 mpg for Toyota and 30.3 for GM with both below the industry target set by NHTSA for 2015. This means that some other competitors will be subject to higher standards (e.g., Honda cars with 36.4 mpg and Ford cars with 35.5 mpg) to elevate the industry average to 31.6 mpg. Toyota and GM, the top two manufacturers in the industry, seem to bear a proportionately lower cost of adjustment. However, in comparison to Toyota, GM can be claimed to have, even if minor, a cost advantage in transition with its combined fleet average being required to reach 30.3 mpg as opposed to 31.5 mpg.

Vehicle mix matters

All simulations were carried out with the current vehicle composition as of April 2008. We know that the CAFE function suggests lower fuel economy standards

for larger vehicles, which seems slightly in GM's advantage. In other words, CAFE standards will be sensitive to the vehicle composition in each category. However, this cost advantage that GM seems to enjoy might cause its market share to decline as consumer preferences shift away from light-trucks and SUVs to smaller and more fuel-efficient cars, as Espey and Nair (2005) predict. This would have altered McManus's (2007) predictions regarding profitability and market share of GM. If willingness-to-pay for higher efficiencies continues to dominate consumer decisions in the face of permanently high gas prices, the competitive position of GM will be contingent on its vehicle mix. The latest plan announced by GM Chairman and chief executive, Rick Wagoner, of ceasing production at four North American assembly plants that make SUVs and pickups by 2010 seems to be in line with this prediction (Vlasic, 2008).

Higher fuel efficiencies possible

Given the influence of higher oil prices that are expected to prevail in the future and the competition pressure, we expect that the new standards will be more effective than expected in improving fuel efficiencies. As Chairman of the Center for Automotive Research, David Cole puts it; "You're going to see people trying to kill each other over how green they can be." (quoted by Maynard, 2007 n.p.).

What is CAFE good for

The fundamental question appears to be what CAFE is good for. Will it really help reduce greenhouse gas emission? Does it only help GM to stay competitive in

the market? We think that CAFE is relatively a more politically motivated policy measure compared with gasoline tax.

As oppose to a gasoline tax, which is claimed to be more effective to reduce oil consumption, CAFE standards seem to allow GM to compete more easily with Toyota, which has a ready competitive advantage in terms of fuel economies. In absence of any regulation on fuel economy, GM would have lost market share with its current fleet as a result of permanently higher oil prices. The new legislation could be thought to provide GM and other US manufacturers a road map to be able to compete with their Japanese rivals which have entered the high-gas-prices era readier than their American counterparts.

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